



Inventing THE Future

2004
ANNUAL REPORT

NASA INVENTIONS AND
CONTRIBUTIONS BOARD





Theron M. Bradley, Jr.

Message from the Chair

Last year, I reported that the productivity of NASA's scientific and technical communities had achieved a record performance. The message I give you this year is equally good. Our technical community continues to produce imaginative, relevant ideas at a record pace. We use best practices to get the job done when the conditions are predictable. We find innovative and often better ways when the tasks are different from what had come before.

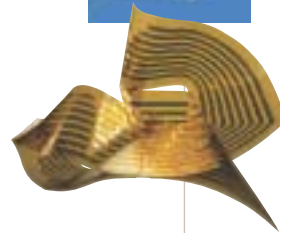
The Inventions and Contributions Board (ICB), overseeing its 46th year of evaluating these ideas and inventions, has rewarded over 1,100 cases in FY 2004 and granted 2,875 individual cash awards to our talented scientists, engineers, mathematicians, and software designers for significant scientific and technical contributions to the Nation's aeronautics and space missions.

These Space Act Awards provide an element of recognition to reflect the pride of the Agency in the awardees and their dedication to the mission in service to the American people.

Join me in celebrating the accomplishments of our technologists and in congratulating those whose efforts will shape the future for humankind.

A handwritten signature in dark ink, reading "Theron M. Bradley, Jr." in a cursive script.

Theron M. Bradley, Jr.
NASA Chief Engineer and Chair of the ICB



Cover: President Kennedy and Dr. Wernher von Braun at Cape Canaveral, FL, on November 13, 1963.
Photo: NASA

Opposite page: An example of NASA's monitoring of Earth's environment, this is Hurricane Frances as seen from the ISS two days before landfall in Florida, September 2004.

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Introduction and Background

What Is an Invention? How the Present Reflects the Past

In selecting this year's theme, we express a universal truth about the nature of ideas. Humans learn from experience. We communicate with each other. We share observations of what we see, hear, feel, taste, and smell. When we face adversity, we try to solve the problem with what we have learned from our past. When that approach fails, we try something new—either from our own ingenuity, or through working together with others to find solutions. We act upon that procedure which seems most likely to succeed and share that idea with the community of our peers.

This is the process of invention. It is the necessary element of human nature that enables progress. It does not matter where ideas come from, only that they are shared and become part of our foundation of knowledge. The idea must first be documented and then examined in the light of the knowledge of peers. Innovation also requires that a leader sees the value and expresses the idea in a manner showing its usefulness to others. Therefore, the communication of ideas (or education) becomes a link between invention and innovation—the adoption of an invention into the mainstream of culture.

Some have great vision and also the ability to lead us more directly into the future. Looking into NASA's past, we see with the certainty of knowledge we have gained and the visionaries who changed their future. President Kennedy gave NASA its challenge in 1962 to send humans to the Moon and return them safely to Earth. Dr. Wernher von Braun had already begun to design and develop rockets that could provide the launch capacity to address the problem. Both had vision. Both looked to the stars as humanity's ultimate destiny. Both had significant impacts on the future.

Kennedy called his vision of the future "The New Frontier." His political ideas laid the groundwork for building strategic alliances and ending discrimination, poverty, sickness, and ignorance. He offered hope for our future. His vision for NASA began with the challenge of landing on the Moon within the decade. Dr. von Braun had a vision for NASA that included building a space station, a Space Shuttle, a lunar base, nuclear propulsion systems such as a nuclear tug, deploying interplanetary vehicles for human and robotic exploration, and, ultimately, creating a scientific and technical platform for conquering the challenges of the frontiers of space. Seen together in the cover photo, you can see the determination in their expressions.

As the new year began, NASA was given a challenge by President George W. Bush. The new NASA Vision rekindles the spirit of the visionaries of our past who continue to shape our future. We shall return to the Moon, establish a colony there, then on to Mars, and then the universe.

Meeting the Challenges of NASA's Vision

On January 14, 2004, President Bush delivered an address at NASA Headquarters, stating a new vision for the Agency with goals for achieving essential milestones. Shortly thereafter, NASA began a transformation to change the way it does business and to recruit new talent. The ICB is in a unique position to measure and monitor the new approaches, benchmarking the productivity of our technology talent from the past against the achievements of our newest resources. So far, our people have not missed a beat in the drums of progress, and the revelations of new ideas come forth at a steady rate.

Throughout FY 2004, NASA's achievements set new pinnacles of success with two successful landings on Mars with Spirit and Opportunity; the successful launch of the fastest air-breathing aircraft ever flown, the X-43A; and fundamental discoveries in science and medicine, some of which are discussed in the 18 exceptional cases acclaimed in this year's ICB Annual Report.



Mathematics, Science, Engineering, and Software

The ICB rewards significant scientific and technical achievement in mathematics, science, engineering, and software. Basic ideas have greater ultimate value than ideas that have been refined. Perhaps this is the reason that the largest awards we have granted have been in fundamental processes in mathematics and software. Scientific advances receive large awards at times but may not yet involve acceptance and implementation by engineers into the technology mainstream, yet the Internet has vastly accelerated the process of adoption.

NASA's recent innovations embrace over 100 fields of exploration. Our support for new languages and operating systems has enabled a technology explosion in computer science. Our needs for wireless communications have resulted in advances in telecommunications. Our requirements for surviving space environments and violent atmospheres on faraway worlds as well as reentry to Earth have led to new materials and processes for their manufacture.

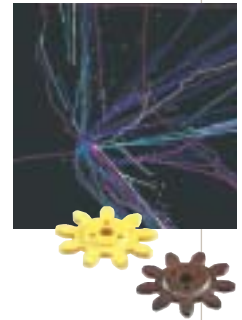
As we learn more, we observe that we know very little. NASA's mission requires that we expand the boundaries of knowledge in every field needed to accomplish our goals. So far, no field has been ignored. We need visionaries from every walk of life, and we value their material contributions.

- NASA publishes much of its documented knowledge in an abstract format in *NASA Tech Briefs*, published in hard copy monthly and also electronically via the Internet. The ICB rewards the authors of the briefs published therein with a nominal award. Last year, 628 awards were given for *Tech Briefs* to be published.
- NASA has been issued over 6,300 patents—nearly one in a thousand of all patents issued by the U.S. Patent Office. Our innovators filed 114 patents in 2004.
- NASA's software developers are among the industry's most prolific. One hundred seventy-five software packages were completed, thoroughly tested and documented, and issued for use last year either to Government projects or to the public.

Successful infusion of new technology into our missions reflects cases where the ICB investigates the claims of the innovators and subjects the ideas to peer review by our members. In 2004, 188 board action cases resulted in awards, 18 of which were judged exceptional by our board. One or more innovators must receive at least \$5,000 for the case to be ruled as "exceptional."

*President George W. Bush
delivers his new vision for
NASA on January 14, 2004.*

Photo: Bill Ingalls, NASA



Progress Measured By Steps

Astronaut Neil Armstrong's famous quote as he stepped down to the Moon's surface, "That's one small step for [a] man, one giant leap for mankind," is burned into the corporate conscience of the human race. He refers to the small step as the last step he took, only a meter or so, but the giant leap of progress it embodied was evident to the world.

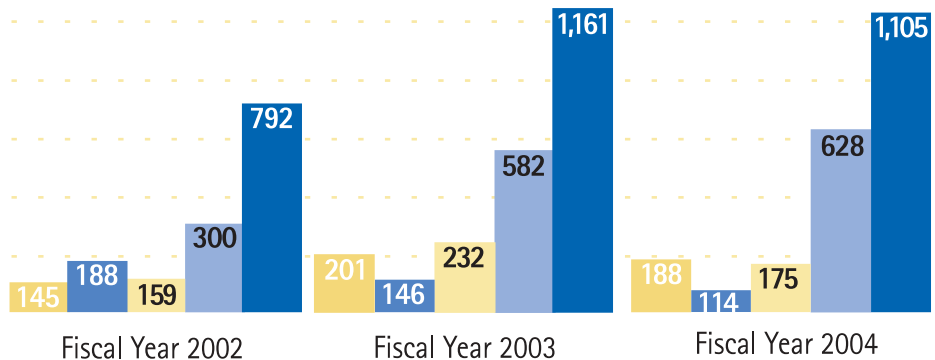
In the 1,105 Space Act award technologies granted in FY 2004, another 1,105 steps in human progress were measured. Some were larger and broader steps than others. Over the years, the ICB has granted 86,000 awards, about two-thirds to contractors and university employees.

You will find references to how NASA's innovations benefit society in many outside publications. Selecting just a few each year, the ICB honors the progress enabled by them.

NUMBER OF AWARD CASES FOR ALL CENTERS

FY 2002–2004
by Category of Award

- Board Action
- Patent Applications
- Software
- Tech Briefs
- TOTALS



18 Steps Into the Future

The following 18 technologies achieved exceptional award status in FY 2004.

1 Rogue OS Real-Time Executive

Courtney B. Duncan, Charles Edward Dunn, Allen H Farrington, and David H. Rogstad,
Jet Propulsion Laboratory (JPL)

NPO-20686-1

With the use of custom architecture and electronic parts, including the Global Positioning System (GPS), Application Specific Integrated Circuits (ASICs), and digital signal processing chips, it was necessary to provide a set of familiar software support and development services for the Rogue Black Jack receivers so that the GPS specific software could be developed, tested, and deployed in place. Commercial products which perform similar functions were expensive, sometimes unstable, poorly matched to the particular problems addressed by the operating system (OS), had many unneeded features, and lacked other features that were critical. The Rogue OS was designed specifically to support GPS operations in space where commercial-style maintenance is not available. The OS is designed to directly run C++ application code, as it has a large number of concurrently operating tasks with requirements for low interrupt latency and precise timing. This OS Executive provides the software backbone for the GPS receiver digital interface to host spacecraft and standard operational and developmental services required by overlaying software programs such as memory management, task switching, I/O services, and debugging support. These systems have been used to collect precise orbit determination data on 15 GPS instruments on 8 spacecraft, including the Shuttle Radar Topography Mission (SRTM), Jason, Grace, IceSat, FedSat, CHAMP, and SAC-C missions, and is planned for the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) satellite constellation.

2 Personal Cabin Pressure Altitude Monitor and Warning System

Jan A. Zysko, Kennedy Space Center (KSC)

KSC-12168-1

Since this case was reviewed last year, several additional valuable applications have been made with this technology. Now it is used to protect workers in the KSC Mars Simulation Chamber from an accidental pump-down to a high-altitude (low-pressure) condition. The KSC T-38 Safety Office is adapting the technology to the astronaut's T-38 fleet for hypoxia prevention, and the Space Shuttle Program environmental control engineers are reviewing the use of these programs for on-orbit operations.

Another potential NASA application that was explored was for the flight crews of mission and administrative aircraft for monitoring and warning of in-flight cockpit and cabin pressurization problems. Commercially, the newest model contains a miniature, but highly accurate, pressure transducer whose readings are further enhanced by employing a collocated temperature sensor to thermally compensate the device. The unit is microprocessor based and is used to interface the sensors, display, and alarm. It not only reads the pressure, but uses the embedded code to solve the mathematical algorithm that converts the indicated pressure readings to altitude, enabling many more applications such as the considerable use in mapping for the Kansas water districts. This case was selected as both NASA's Government and Commercial Invention of the Year for 2003.

3 Tough Soluble Aromatic Thermoplastic Copolyimides

Robert Fox, Nancy Holloway, and Robert Bryant, Langley Research Center (LaRC)

LAR-15205-1, -2

Langley Research Center's Soluble polyimide (LaRC-SI) was originally developed as a matrix resin and high-performance adhesive for advanced aircraft. To that end, this material is proving itself for applications for space environments under NASA's Electronic Parts and Packaging (NEPP) program as a radiation-shielding material and has now moved into the medical industry. A



These items were manufactured using LARC-SI.

unique attribute of LaRC-SI is its solubility characteristics. According to accepted structure-property relationships, this polyimide should be semicrystalline and not exhibit extreme solubility in high boiling polar solvents. When one examines the two derivative homopolymers, based on ODPA or BPDA and 3,4'-ODA, and the analogue copolymer, based on ODPA/BPDA and 4,4'-ODA, these systems are all inherently semicrystalline and insoluble in their imide form. LaRC-SI displays the opposite chemical-physical attribute. Furthermore, this material displays a one-time solubility that has demonstrated the creation of chemically resistant, highly filled microcomposites and multilayer flex circuits by repetitively spraying the material over successive SI photo-etched copper cir-

cuits. LaRC-SI has been used to create carbon/carbon, metal particle transformer cores, mechanical parts and coatings on copper wire, and fiber-optic cable. LaRC-SI is one of the few NASA polyimides that is able to transition itself from purely Government-funded research to commercial production, where benefits to both NASA and the private sector will be realized through increased availability, lower cost, and superior products.

4 Stereo Imaging Velocimetry

Bilal M. McDowell Bomani, Glenn Research Center (GRC)

LEW-17241-1

Stereo Imaging Velocimetry (SIV) is a 3-D full-field quantitative and qualitative analysis tool that is portable and easily adaptable to Shuttle experiments, ground-based investigations, and industrial applications. SIV will permit the collection of quantitative, three-dimensional flow data from any optically transparent fluid seeded with tracer particles. SIV has been utilized for payload planning for experiments on three NASA Shuttle missions (STS-83, STS-94, and STS-107). In addition to providing 3-D fluid flow analysis for Shuttle missions, there are currently five NASA technologies, including Net Charge on Granular Materials (NcharG), Microgravity Observations of Bubble Interactions (MOBI), Colloidal Microscopy/Light Microscopy Module (LMM), and Bi-Component Droplet Combustion Experiment (BCDCE), relying on SIV research in order to

obtain highly accurate fluid flow measurements, interface tracking, biological cell detection, and 3-D object recognition. Collaborating with industry via Space Act Agreements, SIV technology has helped over 10 industrial partners solve complex problems in the areas of continuous casting, railroad track welding, vacuum cleaner analysis, biological cell labeling and tracking, softball bat performance analysis, lawn mower flow analysis, and golf ball performance analysis. NASA has received royalty payments from Digital Interface Systems, Inc.

5 NASA High Strength Aluminum Alloy for High-Temperature Applications

Jonathan A. Lee, Marshall Space Flight Center (MSFC), and Po Shou Chen, Morgan Research Corp.

MFS-31294-2-C1P2-1

Originally developed by NASA as high-performance piston alloys to meet U.S. automotive legislation requiring low exhaust emission, the novel NASA alloys now offer dramatic increase in tensile strength for many other applications at elevated temperatures from 450°F (232°C) to about 750°F (400°C). The material has recently been identified as a candidate for the new RL60 upper-stage engine, which will be a higher thrust class engine to replace the RL10 engine. The new engine will offer throttling capability ranging from 50,000 to 65,000 lbs. of thrust. The RL60 engine is being developed to provide lift capability growth for U.S. vehicles, such as Atlas and Delta, and also international launch vehicles. It can be produced very economically from conventional permanent mold, sand casting or investment casting, with silicon content ranging from 6 percent to 18 percent. At high silicon levels, the alloy exhibits excellent dimensional stability, surface hardness, and wear-resistant properties. The secret ingredients are copper (5.6–8 percent) and magnesium (0.5–1.5 percent) alloying agents and specialized heat treatments that increase yield strength, ductility, and enhance useful life significantly—as much as four times. The patent is licensed to Bombardier Motor Corporation of America, who manufactures the famous Envirodite boat engines.

6 Mars Lander

Michael C. O'Neal, Tommaso P. Rivellini, and Robert M. Bamford, Jet Propulsion Laboratory (JPL)

NPO-19859-1 and 19925-1

The last successful missions to Mars all incorporate this invention—a tetrahedral-shaped lander surrounded by four airbags to cushion the impact with Mars. The significance of the invention is that it represents the most robust landing system ever flown to a planet. The combination of a rugged omnidirectional landing airbag and a self-righting lander enables targeting landing sites that could not be targeted with traditional landing systems. Additional significance of the invention is that the tetrahedral shape provides an inherently rigid structural design that can house a wide variety of payloads. The tetrahedron provides a structure that has omnidirectional load-carrying capability, enabling the transport of easily carrying bouncing and rolling loads associated with an airbag landing. Also, the tetrahedron enables automatic self-righting when the three sides are articulated away from the base side.

There are four main aspects of the invention.

1. **Tetrahedral Lander Structure**—The tetrahedral lander structure provides structural support for all of the payload and equipment. It also provides structural support for the launch, entry, and landing loads. The lander structure is constructed as three identical side petals hinged around a single base petal. The hinges are motorized to allow the tetrahedron to open after landing. During launch entry and landing, the side petals are bolted shut to provide a rigid structure. After landing, the side petals are released to allow them to open. The structure is unique in that it uses simple two-dimensional structural elements (the petals) to create a strong, rigid three-dimensional structure (tetrahedron).
2. **Four Airbags**—The airbags are an integral part of the lander system. The airbags and the lander structure are designed specifically to accommodate each other. The primary structural load paths of the airbags are designed to coincide with geometric hard points on the lander. The airbags interface to the lander only through discrete structural cable called tendons. The fabric membrane of the airbags is not directly attached to the lander structure. Each of the four airbags is composed of six interconnected lobes. This creates a single open volume inside the airbag, but looks like 24 distinct spheres pressed together when viewed from the outside. The advantage of this design approach is that it allows large airbags to be fabricated, but minimizes the radius of curvature of the bags (this minimizes the skin stresses and helps the airbags survive impact loads). Each of the three side petal airbags is connected via a vent to the base petal airbag. This improves the overall energy-absorbing efficiency of the airbag system. Another key aspect of the design is that it has nearly uniform performance in all orientations, thereby allowing the lander to bounce and roll without detrimental effects on loading.
3. **Mechanisms**—There are two primary mechanisms that are essential to the design of this system. Airbag Retraction Actuators are used to pull in the airbag fabric after a landing. The fabric must be pulled in to prevent covering the inside of the lander when it opens. Lander Petal Actuators are used to open and self-right the lander after the airbags have been retracted. The lander has been designed so that the act of opening the side petals forces the lander to automatically self-right.
4. **Payload**—The lander system is designed to be able to house a wide variety of payloads. The area enclosed by the tetrahedron as well as the wall of the tetrahedral structure can be used to house electronics, mechanisms, and science instruments.

7 Adhesive Bubble Removal Technique and Fixture for Fiber-Optic Applications

John Kolasinski, Goddard Space Flight Center (GSFC)

GSC-13874-1

This technology is a fixture and method to eliminate adhesive bubbles during fiber-optic component termination or connector assembly procedures. Bubbles trapped in adhesives can cause serious latent problems in fiber-optic components, including optical fiber movement (pistoning) and cracking, resulting in premature assembly failure. With this technology, adhesive-filled components are placed in the fixture while the adhesive is still liquid, which is then spun in a centrifuge. The centrifuge drives bubbles out of the adhesive, while the innovative fixture prevents liquid adhesive from being expelled in the centrifuge using a unique holding and sealing system. Several

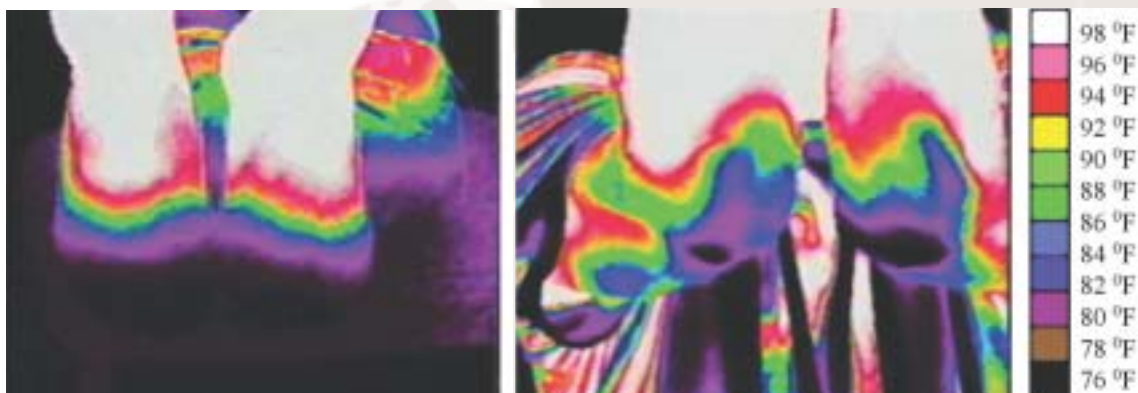
highly visible and successful projects, including Rossi X-Ray Timing Explorer (RXTE), Tropical Rainfall Measuring Mission (TRMM), Hubble Space Telescope Solid State Recorder (HST SSR), Earth Observer 1 (EO-1), and Wilkinson Microwave Anisotropy Probe (WMAP), have used this innovation to ensure the reliability of mission essential fiber-optic command-and-control databases.

8 High Resolution and High Performance Quantum Well Infrared Photodetector (QWIP) Cameras for Space Exploration, Defense, Medicine, and Commercial Use

Sarath D. Gunapala, Sumith V. Bandara, and John K. Liu, Jet Propulsion Laboratory (JPL)

NPO-19815-1, -30624, -19669, -20521, -30507, and -20703

There is a very significant change in the value of this contribution since the last evaluation. The inventors have improved the spatial resolution of the QWIP cameras by a factor of five, dynamic range by a factor of four, and the sensitivity by 100 percent, as mentioned in the New Technology Reports. In addition, they reduced the size, weight, and power consumption of the camera by 30 percent. These cameras are planned for use in the new Hyper Spectral Imager sensor development by Goddard, hazard detection and avoidance on future MARS landers, and the cross-cutting technology program known as the Static Spectral Imager sensor. In January 2003, the U.S. Food and Drug Administration approved use of the QWIP camera-based BioScan System II for breast tumor detection application. QWIP cameras based on this high-resolution and high-performance technology also are being used to detect melanoma skin cancer and in the treatment of various cardiovascular diseases at Cornell Medical School and the University of Southern California's Children's Hospital. High-resolution QWIP cameras are being used in the Air Force and Missile Defense Agency's Air Borne Laser Laboratory aircraft to search and track incoming enemy missiles. Several large format (640x512) QWIP focal plane arrays are now in use at the Palomar 200-inch Hale telescope. Canada uses these cameras for highway hazard (i.e., black ice and wildlife) detection and warning systems. OmniCorder Technologies, Inc. and QWIP Technologies have obtained licenses from Caltech to commercialize this technology. These companies have predicted the market value of this technology at over \$2 billion in the next few years.



These images of a pair of human feet were taken with the QWIP infrared camera to examine the blood flow distribution in the toes, reflecting a circulatory ailment that is to be treated.

9 FACET: Future Air Traffic Management Concepts Evaluation Tool

Banavar Sridhar, Karl Bilimoria, and Shon Grabbe, Ames Research Center (ARC); Gano Chatterji and Kapil Sheth, Raytheon ITSS; and Daniel Mulfinger, University of California, Santa Cruz

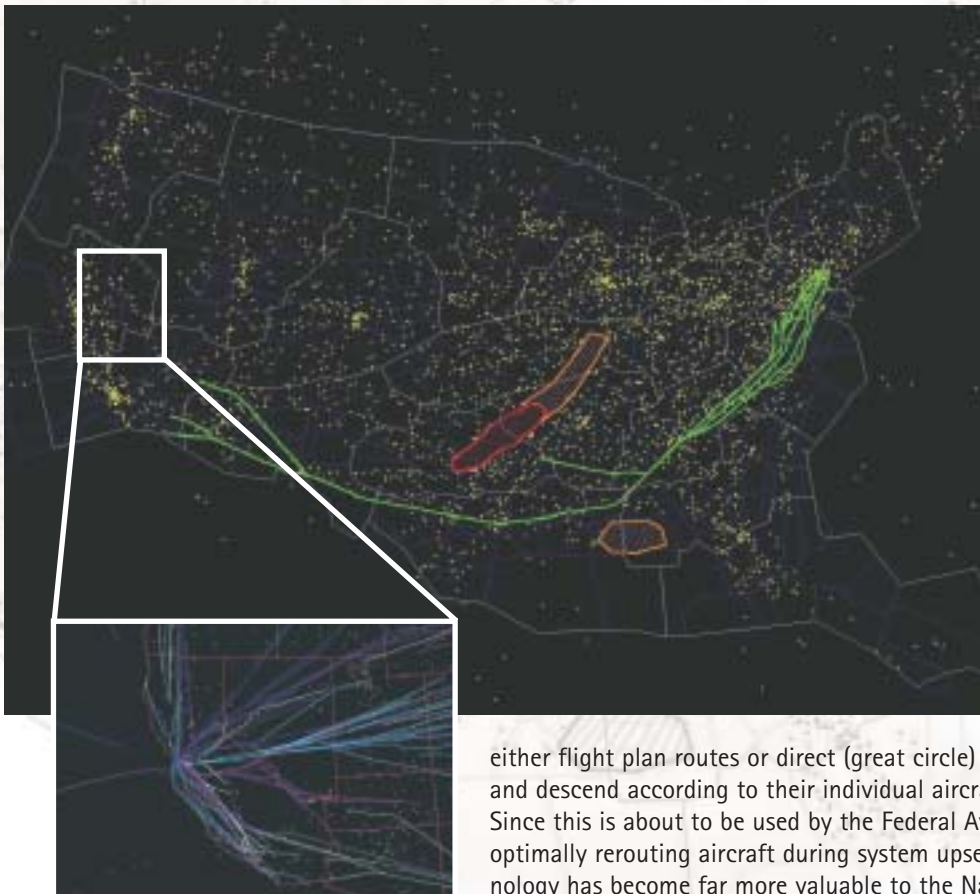
ARC-14653-1

FACET is a flexible software-based simulation environment for exploration, development, and evaluation of advanced air traffic management (ATM) concepts. Examples of concepts studied using FACET are: aircraft self-separation for free flight, modeling and prediction of air traffic

controller workload, a decision-support tool for direct routing, integration of space launch vehicle operations into the U.S. National Airspace System (NAS), and advanced traffic flow management techniques using rerouting, metering, and ground delay. FACET models system-wide airspace operations over the contiguous U.S. airspace. Models (e.g., center/sector boundaries, airways, locations of navigation aids and airports) are available from databases. Weather models (winds, temperature, bad weather cells, etc.) also are available. FACET models aircraft trajectories using round-earth equations.

Aircraft can be flown along

either flight plan routes or direct (great circle) routes as they climb, cruise, and descend according to their individual aircraft-type performance models. Since this is about to be used by the Federal Aviation Administration for optimally rerouting aircraft during system upsets beginning this fall, the technology has become far more valuable to the Nation.



This is a FACET screen shot currently in use by the FAA for visualizing air traffic rerouting procedures.

10 NASA DeBakey Heart Pump Tubular Coupling

Bernard J. Rosenbaum, Johnson Space Center (JSC)

MSC-22865-1

This improvement to the NASA deBakey left ventricular assist device (LVAD) heart pump provided a means to secure the flexible outflow cannula to the coupling which permits the flexible cannula to be separated from the pump, greatly facilitating the task of attaching the cannula to the

blood distribution system. When completed, it allows the pump to be quickly installed, providing a leak-proof connection and a sufficiently smooth transition at the connection site to avoid formation of a blood clot. The new design is now incorporated into the deBakey LVAD, which has been recently approved by the FDA for a pediatric application and, in fact, implanted in a 6-year-old girl in Houston in March 2004. This aspect of the overall invention enables the device to provide the lowest amount of hemolysis and longest implantation life of all known LVADs, making it possible to alleviate the suffering and increase the lifespan of millions of people.

11 Perilog: Contextual Search and Retrieval Software Tools

Michael Wallace McGreevy, Ames Research Center (ARC)

ARC-14512-1

Perilog is a collection of patented and patent-pending text mining methods and software that exploit latent linguistic structure in seemingly unstructured text. The currently distributed version of Perilog software includes keyword-in-context search, flexible phrase search, search by example, phrase generation, and phrase extraction. These high-level tools are based on a hierarchical toolkit of Perilog programs consisting of approximately 13,500 lines of code in several hundred executable units of varying complexity. Developers can access all of the Perilog software via the Unix command line, invoking commands ranging from high level (e.g., "keyword.search") to low level (e.g., "gen.highlight.model"). End users, such as managers, pilots, human factors researchers, and database operators, can access an integrated suite of Perilog's tools via a user-friendly Perilog software package that has a browser-based graphical user interface (GUI). The end-user version of Perilog has been in operational use at the NASA/FAA Aviation Safety Reporting System (ASRS) and at Southwest Airlines since early 2002, where it is used to search databases of incident reports. The entire package of Perilog methods and software has been distributed under Government agreements and licenses to private companies, universities, and elsewhere since mid-2001.

12 Hierarchical Image Segmentation (HSEG), Its Recursive Formulation, and the Associated HSEG Viewer Program

James Tilton, Goddard Space Flight Center (GSFC)

GSC-14681-1, 14305-1, 14331-1

The HSEG algorithm produces a set of hierarchically related image segmentations or segmentation hierarchy. This offers more flexibility and power for image analysis applications than other segmentation procedures that offer just one segmentation result. A segmentation hierarchy is a set of several image segmentations of the same image at different levels of detail in which the segmentations at coarser levels of detail can be produced from simple merges of regions at finer levels of detail. The manner in which regions evolve through the segmentation hierarchy provides additional information that can be used for object identification. This is in addition to the segmentation information, which allows the transformation of image analysis from a pixel-by-pixel basis into an object-by-object basis. This has many advantages. It allows the use of object shape, texture information, as well as contextual information in image analysis, enabling a more accurate and robust analysis. To be useful in image analysis, image segmentation must be fast and

accurate. The HSEG algorithm utilizes a finely controlled hierarchical step-wise optimization process to produce highly accurate image segmentations. The recursive formulation of HSEG (RHSEG), complete with highly efficient processing window artifact elimination code, provides processing speed. The HSEGViewer program provides a convenient, user-friendly utility for visualizing and interacting with the image segmentation hierarchies produced by the HSEG/RHSEG programs. Bartron Medical Imaging is using HSEG/RHSEG to generate hierarchical image segmentations of medical imagery data (mammograms, dental x rays, microscopic images of pathogens, etc.), and the HSEGViewer program is being used to provide medical practitioners with a means to examine the hierarchical image segmentations of their medical imagery data. This system is intended for use in assisting medical practitioners in the diagnosis of medical conditions. HSEG/RHSEG and HSEGViewer are key components of this system.

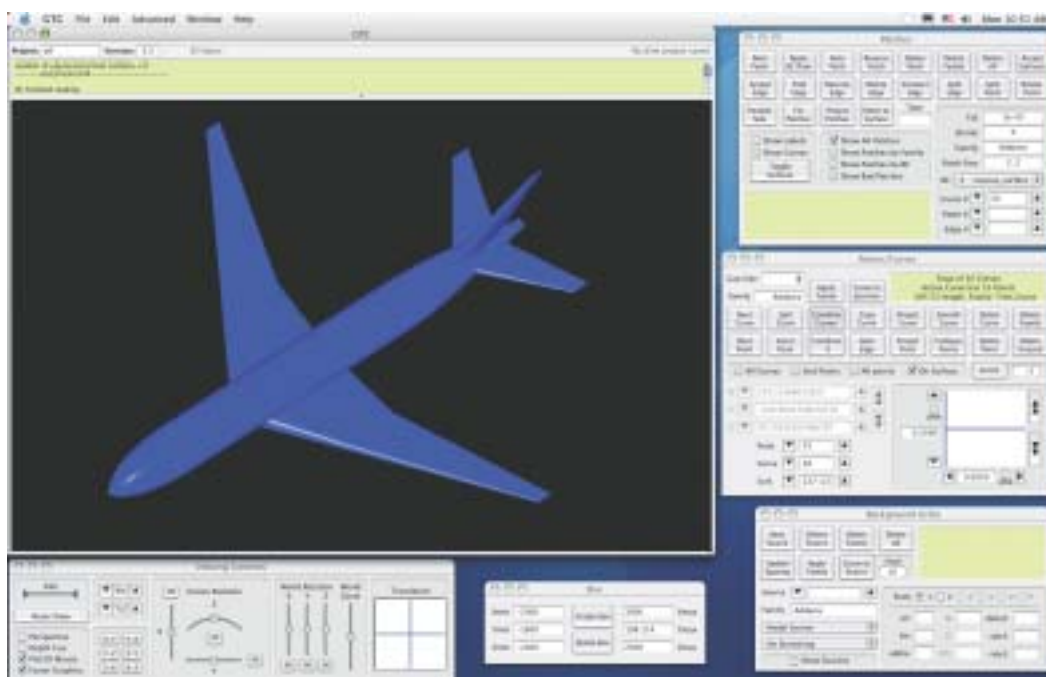
13 TetrUSS 2004: Tetrahedral Unstructured Software System

Khaled S. Abdol-Hamid, Neal T. Frink, Craig A. Hunter, Paresh C. Parikh, Shahyar Z. Pizadeh, and Jamshid A. Samareh, Langley Research Center (LaRC); Matthew J. Grismer, Air Force Research Lab; Maharaj K. Bhat, Paragon; and Mohagna J. Pandya, Swales Aerospace

LAR-16882-1

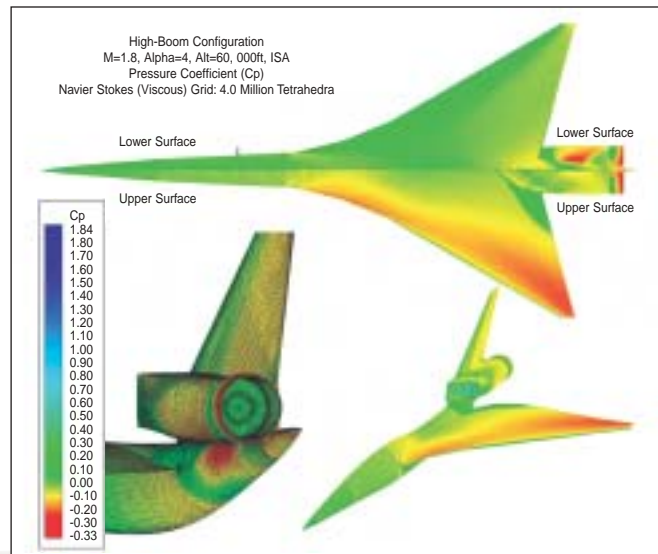
Key changes in TetrUSS since the last evaluation in 1996 include the following. 1) The addition of a viscous grid/Navier-Stokes capability makes TetrUSS a predictive, not a reactive, tool for aviation and exploration. 2) Expansion to other hardware platforms, using the OpenGL standard, allows TetrUSS to be used on the Mac OSX and PC Linux platforms rather than just the SGI/Irix solution previously implemented. 3) Advanced turbulence models add capability to the USM3D flow solver for simulating complex aerodynamic configurations with propulsion integration using

two equation turbulence models. The overhead of using these models is less than 5 percent of the total computer time and 1 percent of memory. As accurate unstructured-grid CFD methods become available for complex aerodynamic applications, the design and analysis time of complex configura-



Screen shot of TetrUSS 2004, which was chosen for the second time as NASA's Software of the Year.

tions will be dramatically decreased when compared with structured-grid generation. 4) A parallel version of USM3D flow solver allows virtual linear scalability for problem solving with up to 250 processors, reducing processing time by nearly 250-fold. 5) An adaptive grid refinement method is being developed and successfully applied to several 3-D problems. The method is based on automatic local grid refinement. As the flow solution proceeds, areas in the computational domain, which require more accuracy, are identified. The grid is then automatically refined in these areas, and a new solution is obtained. The process continues until a predetermined objective (usually an accuracy level) is achieved. This is the first time an adaptive unstructured grid was implemented for viscous flow modeling. 6) Use of TetrUSS in critical NASA, Government, and industry programs has increased. TetrUSS is now in use at over 500 sites for all classes of aerospace and industrial fluid flow applications, inside and out of NASA, and is worth many billions of dollars.



This simulation was performed using TetrUSS 2004 for an advanced commercial transport concept.

14 Turbomachinery Aeroelastic Analysis Code (TURBO-AE)

Milind A. Bakhle, Dale E. VanZante, John J. Adamczyk, Eric R. McFarland, George L. Stefko, Theo G. Keith, Jr., and Wai-Ming To, AP Solutions, Inc.; John J. Barter, GE Aircraft Engines; Jen-Ping Chen and J. Mark Janus, Mississippi State University; David Whitfield, University of Tennessee; Rakesh Srivastava and Aamir Shabbir, University of Toledo

LEW-17514-1

The propulsion aeroelastic analysis code TURBO-AE enables detailed high-fidelity modeling of aeroelastic and unsteady aerodynamic characteristics for the prediction of flutter, forced response, performance, and blade-row interaction effects in turbomachinery blade rows. Flutter is a self-induced phenomenon where vibrating blades of a turbomachinery blade row extract energy from the surrounding fluid. This extracted energy feeds the vibrating motion, resulting in a catastrophic failure of the blade. Forced response is a phenomena induced by an external source of excitation that results in resonant vibration of the turbomachinery blade row causing the blades to fail prematurely because of high cycle fatigue (HCF). Both flutter and forced response are fluid-structure interaction problems that result in catastrophic failures of turbine engine blades. Catastrophic blade failure could lead to the loss of the engine or even the aircraft. Once encountered, they are not only costly to correct, but also result in program delays, redesign, and downtime for the entire fleet of engines. Therefore, it is critical to accurately predict these phenomena during the design and manufacture of turbomachinery. The use of the TURBO-AE code will help designers to be more aggressive and develop more efficient and quieter engine designs. An efficient design will result in reduced fuel consumption, thereby reducing weight and decreasing the CO₂ emissions. Reduced fuel burn and reduced emissions not only help reduce operating costs for the operator, but also directly help the environment.

15 SmartCam3D (SC3D) Software

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MSC-23795-1

SC3D is a hybrid synthetic vision system (HSVS) that combines live sensor data with information from a synthetic vision system (SVS). By combining the dual information sources, the operators are afforded the advantages of each approach. The live sensor system provides real-time information for the region of interest. The SVS provides information-rich visuals that will function under all weather and visibility conditions. Additionally, the combination of technologies allows the system to circumvent some of the limitations from each approach. Video sensor systems are not very useful when visibility conditions are hampered by rain, snow, sand, fog, and smoke, while an SVS can suffer from "data freshness" problems. Typically, an aircraft or satellite flying overhead collects the data used to create the SVS visuals. The SVS data could have been collected weeks, months, or even years ago. To that extent, the information from an SVS visual could be outdated and possibly inaccurate. The SC3D system will improve the nature of space flight. In the words of an astronaut who has used SC3D, "In 5 years, everything we fly will have SmartCam3D or something like it in the cockpit." The SC3D system is supporting NASA's endeavors related to mission planning, flight operations, flight/aviation safety, visualization requirements definition for future spacecraft, return-to-flight activities (orbiter inspection), and education outreach. The SC3D system has many features not found in any other HSVS. The following list constitutes major advancements in the state of the art: 1) a PC-based software algorithm that allows for the real-time fusion of video and SV graphics; 2) an intelligent horizon model that provides a high-resolution ground model for the region of interest (ROI) and automatically fills the remainder of the field of view (FOV) with course topography; 3) a custom heads-up display (HUD) capability that includes a core set of built-in widgets (pitch ladder, dial, bank indicator, digital, etc.) that can be "drag-n-dropped" into the application and linked to a data source easily; 4) a real-time on-orbit, reentry, and ground visualization for Earth and non-Earth-based (Moon, Mars, etc.) environments; and 5) a picture-in-picture feature that greatly increases the FOV by displaying HSVS data in a rectangle in the center of the screen and SVS data for the remainder of the FOV.

Additional features that constitute advancements in the state of the art include: 1) a creation and annotation system that allows users to place and annotate 3-D items (tunnel-in-the-sky, no-fly zones, airspaces, buildings, etc.); 2) an open source and easy-to-use interface library that provides an application programming interface (API) to easily connect simulators, vehicle data streams, playback systems, and so on, to the SC3D system; and 3) a north-up and vehicle-up map display that supports the addition of overlays.

16 Marshall Aerospace Vehicle Representation in C II (MAVERIC II)

James W. McCarter, Marshall Space Flight Center (MSFC)

MFS-31989-1

MAVERIC II is an in-house-developed software environment that facilitates the rapid development of high-fidelity flight simulations for launch, orbital, and reentry vehicles of any user-defined configuration for all phases of flight. It has become NASA's primary tool for simulating space transportation vehicle designs. It combines multiple subsystems and facilitates functional integration of a vehicle

design. The X-37 Program uses MAVERIC II as its primary NASA insight simulation tool, for both the approach and landing test vehicle (ALTV) and for the orbital vehicle (OV). It is in the process of being validated against the contractor's ALTV simulation. The MAVERIC II X-37 simulation has been used to assess the robustness of the guidance, navigation, and control (GN&C) to random dispersions as well as extreme off-nominal conditions. It has been essential in gaining the necessary insight into the GN&C and the performance of the vehicle. It will be used for extensive Monte Carlo analysis as well as stress testing. It also will be used to assess failure scenarios and mitigate risk.

17 Chemical Equilibrium with Applications (CEA) Including Associated Software

Bonnie J. McBride, Russell W. Claus, and Minna M. Chao, Glenn Research Center (GRC)

LEW-17687-1

The NASA computer program CEA calculates chemical equilibrium compositions and properties of complex mixtures. The applications include assigned thermodynamic states, theoretical rocket performance, Chapman-Jouguet detonations, and shock-tube parameters for incident and reflected shocks. CEA represents the latest in a number of computer programs that have been developed at GRC during the last 50 years. These programs have changed over the years to include additional techniques. Associated with the program are independent databases with transport and thermodynamic properties of individual species. Over 2,000 species are contained in the thermodynamic database. The program is written in ANSI standard FORTRAN and is in wide use by the aerodynamics and thermodynamics community, with over 2,000 copies in distribution. This is a reevaluation of the 1993 Exceptional Award case known as CET 1989 based on innovations made subsequently.

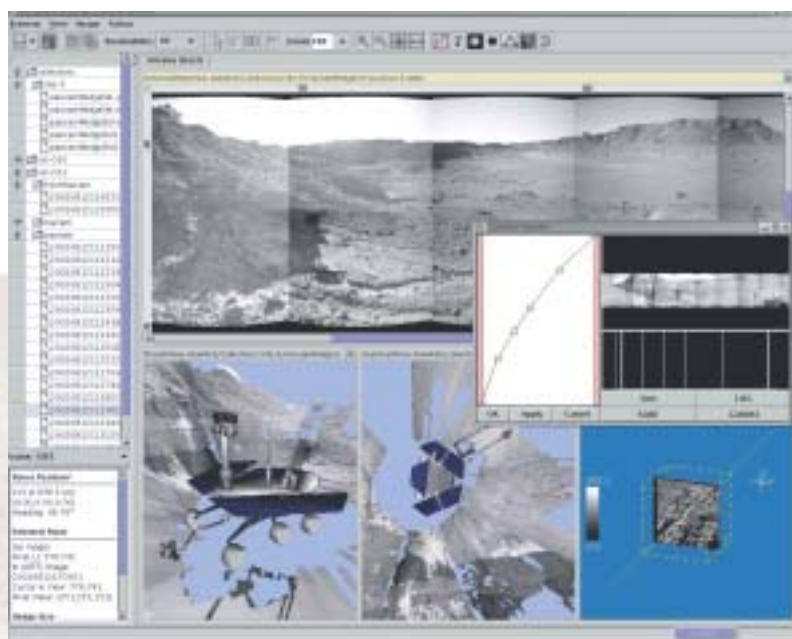
18 The Science Activity Planner (SAP)

Jeffrey S. Norris, Mark W. Powell,
Marsette A. Vona, Paul G. Backes,
and Justin V. Wick, Jet Propulsion
Laboratory (JPL)

NPO-41028-1

The SAP combines cutting-edge visualization with sophisticated planning and simulation capabilities to provide an intuitive interface to Mars rovers and landers. It is a multimission, multipurpose tool that has achieved three simultaneous successes in

*This is a SAP screen shot on the Mars
Exploration Rover mission. The SAP
is a co-winner of the 2004 NASA
Software of the Year award.*



mission operations, public outreach, and technology development. SAP comes in two versions. The first is used in mission operations and contains the official mission activity dictionary. The second version was released under the name Maestro to the public for education and outreach. Maestro includes additional training features that make it a more effective tool for public engagement. SAP is used heavily in the Mars Exploration Rover (MER) mission on a daily basis. Scientists on the MER mission depend on SAP as their primary interface to the Spirit and Opportunity rovers. Every day, mission scientists and engineers use SAP to plan the next actions of the rovers and analyze the data arriving from Mars. SAP is a Class-A, mission-critical part of the rovers' operations subsystem and is a vital part of mission operations. SAP has completed well over 250 sols of successful mission operations of the Spirit and Opportunity rovers without a single critical failure and will continue to serve this role until the end of the extended mission.

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Information about the ICB and its programs may be viewed at the NASA Web site:
<http://icb.nasa.gov>.

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The key contact in the process for an application for patent waiver, and for advance
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